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A COMPARISON OF THE AMERICAN BROWN-ROT FUNGUS WITH SCLEROTINIA FRUCTIGENA AND S. CINEREA OF EUROPE

W. A. Matheny

(WITH SIX FIGURES)

Is the American brown-rot fungus (*Sclerotinia fructigena*) of stone fruits identical with the fungus bearing the same name and occurring throughout Europe, but there found exclusively upon pome fruits? That *S. fructigena* should occur in Europe only on pome fruits and in this country only on stone fruits appears unusual and to many improbable. If *S. cinerea* is the fungus attacking stone fruits in Europe, as all the European writers maintain, then the suggestion seems pertinent that our brown rot of stone fruits is caused by the same fungus. In fact, ADERHOLD and RUHLAND (5) assert that our species is *S. cinerea*. They came to this conclusion after an examination of a few preserved apothecia sent them by NORTON, and in the absence of a more extended study their evidence appears inconclusive.

At the suggestion of Professor C. F. HODGE of Clark University, the writer has undertaken a comparative study of these two species. At first it was intended merely as a study in variation, but it soon of necessity became a problem in taxonomy. Our final interest was to determine as nearly as possible which one of the above species agrees more nearly with the rot of our stone fruits.

Historical sketch

The history of *Sclerotinia fructigena* dates back to 1796, when PERSOON (17) gave the name *Torula fructigena* to a fungus which he found on the decayed fruit of *Prunus domestica*, *Amygdalus persica*, and *Pyrus*. This same name was retained by other writers, notably FUCKEL (12), ALBERTINI and SCHWEINIZ (6), SACCARDO (23), and RABENHORST (21). In 1801 PERSOON (18) changed it to *Monilia fructigena*, a name by which it is generally known today. KUNZE and SCHMIDT (14) a little later referred it to *Oidium fructigenum*, under which name it received attention from many writers, among the first of whom should be mentioned EHRENBERG (10), COOKE (8), DUBY (9), and FRIES (11). In 1822 PERSOON (19) renamed this fungus *Acrosporium fructigenum*, a classification which was never accepted by other writers. WALLROTHIO (29) placed it in the genus *Oospora*, calling it both *O. candida* and *O. fructigena*, while VON THÜMEN (27) first classed it as *Oidium Wallrothii*, but later (28) changed it to *O. fructigenum*. The first writers to attach any economic importance to this fungus were VON THÜMEN (28) and HALLIER (13). SCHRÖTER (25) in 1893, being confident of its ascomycetous nature, placed it in the genus *Sclerotinia*. This classification was confirmed in Europe in 1904 by ADERHOLD (1). NORTON (16) had first discovered apothecia in 1902.

Sclerotinia cinerea was first described as *Monilia cinerea* by BONORDEN (7) in 1851. He noted it forming small, gray, sometimes brownish conidial tufts on fruit. This species has many times been confused with *S. fructigena*, in fact many of the descriptions given the one could apply equally well to the other. SACCARDO (23) in 1886 recognized *Monilia cinerea*, while SCHRÖTER transferred it to the genus *Sclerotinia* along with *M. fructigena*. WORONIN (30) in his excellent study published in 1900 established beyond a doubt the fact that the species are distinct. This opinion is held by SORAUER (26).

Difference between S. fructigena and S. cinerea

Several points of difference between these two species have been cited by ADERHOLD (2, 3, 4), WORONIN (30), and others. Of these, the most striking are as follows:

1. The conidia of *S. fructigena* are always larger than those of *S. cinerea*.

2. There is a difference in shape of the conidia, those of the former having an elongated ellipsoidal form, while those of the latter are more rounded.

3. The conidial tufts of *S. fructigena* are light brownish-yellow or ocher and are always large, while those of *S. cinerea* are ash-gray

and always small. It is noted that the conidial tufts of the former often grow together, exhibiting a smooth upper surface. This does not occur with the latter species.

4. *S. fructigena* occurs on pome fruits, while *S. cinerea* occurs on stone fruits.

5. The ascospores of *S. fructigena* are sharply pointed at the ends, while those of *S. cinerea* are rounded on the ends. The former are without oil droplets, the latter possess them.

Observations

Our observations in this study are limited to behavior on fruit and in pure culture, size of conidia, and size of asci and ascospores. No apothecia could be obtained from Europe; however, the measurements made by ADERHOLD and RUHLAND were available.

In the beginning, letters requesting pure cultures or mummied fruits bearing both species were sent to different parts of Europe. Pure cultures of *S. cinerea* and *S. fructigena* were twice sent me by Dr. J. WESTERDIJK of the Association internationale des botanistes, Bureau pour la distribution de cultures de moisissures, Amsterdam. Mummied fruits bearing *S. fructigena* were sent me by the following persons: Dr. LUIGI MONTEMARTINI of the University of Pavia; Professor Dr. C. WEHMER of Hannover; Professor Dr. PAUL SORAUER of Berlin; GY DE ISTVANFFI of Budapest; and Professor Dr. G. LUSTNER of Geisenheim. Similar fruits were also obtained from the government experiment stations at Geisenheim and Dahlem. I also received a box of mummied fruits from the Department of Agriculture of New South Wales.

Among the fruits sent me by Dr. LUSTNER were some mummied plums bearing *Sclerotinia cinerea.* Its outward appearance was so strikingly different from that of *S. fructigena* that its recognition was a matter of first glance. Both species were easily isolated on other fruits and then in pure cultures. This plan gave an easy and practical method of observing the forms as they grew side by side, many times on the same pear or apple and oftentimes in the same petri dish.

BEHAVIOR ON FRUIT.—Quinces taken from the same tree, and subjected to the same external conditions, were inoculated with

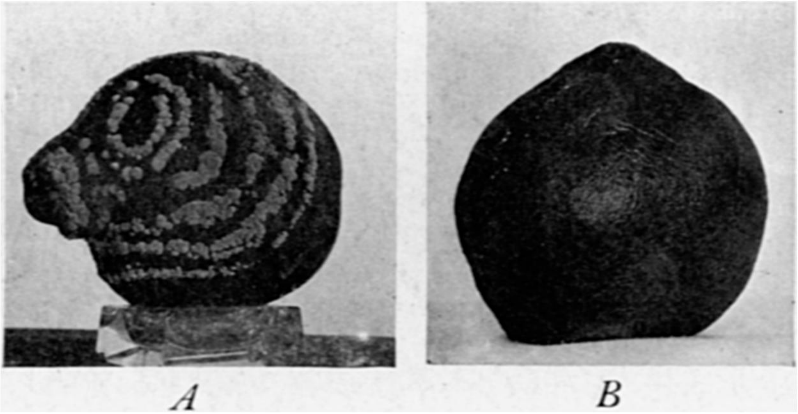

FIG. 1.—*A*, quince bearing the European *S. fructigena;* conidia taken from a mummied fruit obtained from Dr. P. SORAUER of Berlin; *B*, quince taken from the same tree as *A*, but inoculated with local *Sclerotinia* spores; quinces inoculated with the European *S. cinerea* behaved in a similar way.

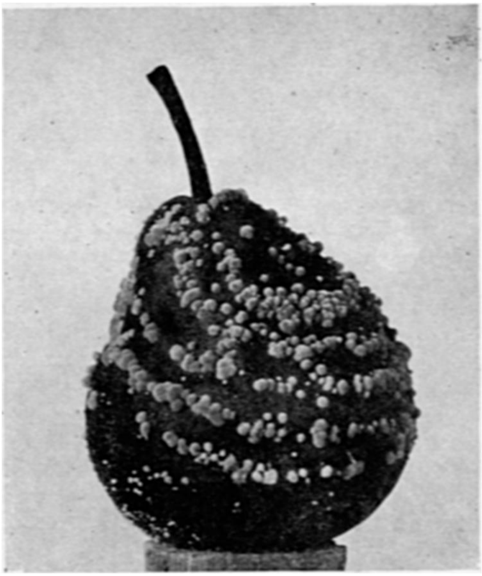

FIG. 2.—*S. fructigena* on a pear; inoculated from a fruit obtained from Dr. C. WEHMER of Hannover.

conidia of *S. fructigena* and of *S. cinerea* which were sent from Europe, and with conidia from *Sclerotinia*-infected plums growing in Worcester. The growth of *S. fructigena* was very slow, however, producing in two weeks large, yellowish conidial tufts which arrange themselves in rings (fig. 1, *A*). The quinces inoculated with *S. cinerea* and the local *Sclerotinia* behaved in exactly the same way, both turning the fruit brown but producing no conidia. In different varieties of apples, 25 experiments gave exactly similar results as those obtained with the quinces, that is, large, yellowish conidial tufts from the *S. fructigena*, and no conidia at all from the *S. cinerea* and the local *Sclerotinia*. If the apples were cut in quarters, and the conidia placed directly on the exposed flesh of the fruit, an abundant growth of spores was obtained. Quartered apples inoculated in this manner with the spores of *S. fructigena* always gave large, yellowish tufts of conidia. When *S. cinerea* was used, the conidia appeared in small ash-gray tufts entirely unlike those of *S. fructigena*. The local *Sclerotinia* spores produce

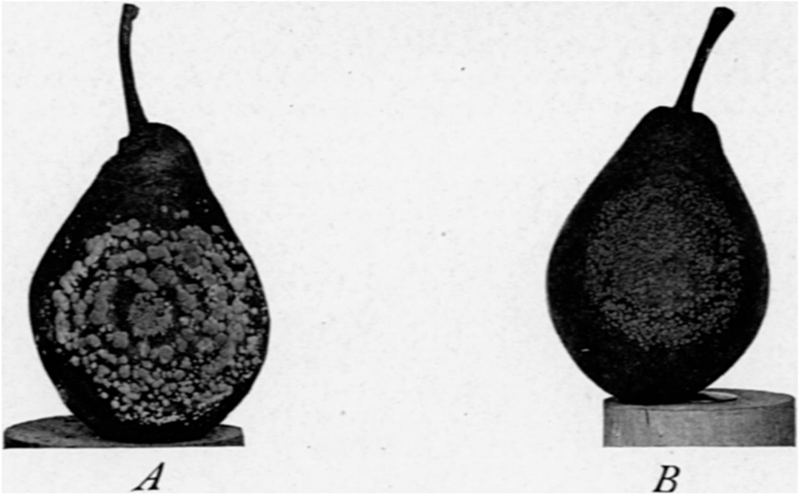

FIG. 3.—*A*, *S. fructigena* on a pear; inoculated from fruit obtained from Dr. LUIGI MONTEMARTINI of Pavia; *B*, local *Sclerotinia* on a pear exactly similar to *A*; this pear was inoculated 10 days after *A*, and both photographed the same day, 13 days after the inoculation of *A*.

conidia a little sooner than those of *S. cinerea*, but in other respects their resemblance is very close.

On pears, 100 experiments were tried. With the *S. fructigena* inoculations the results were uniformly the same as on the quince and apple. The growth was much slower than that of the local *Sclerotinia* on similar fruit, but the usual large, yellowish conidial tufts were produced (fig. 2).

The European *S. fructigena* and the local *Sclerotinia* were grown many times on the same pear (figs. 3 and 4), and the results were no different from those obtained when they were grown separately.

BEHAVIOR IN PURE CULTURE.—Pure cultures of the European *Sclerotinia fructigena* and of the local brown-rot fungus have been grown side by side during the past year (fig. 5). Hundreds of cultures of each have been maintained on various media: plum agar, bread agar, beet decoction, apple gelatin, etc. It was thought that should these fungi be identical, a similarity in cultural growth might appear in some of these media. No evidence of any such similarity has so far been observed. Cultural characteristics of each are as distinctly different today as they were one year ago when this experiment was started.

Comparison of the conidia of S. fructigena, S. cinerea, and local Sclerotinia

In the accompanying table are arranged the comparative sizes of the conidia of *S. fructigena* and *S. cinerea* as they have been given by different writers.

AUTHOR	CONIDIA	
	S. fructigena	*S. cinerea*
Saccardo (**23**)	25×10–12	15–17×10–12
Lindau (**15**)	20–24×12–14	12–13×9–10
Woronin	20.9 ×12.1 to 24.5 ×13.2	12.1 × 8.8 to 13.2 × 9.9
Schröter	18–24×10–12	15–18×10–12
Aderhold and Ruhland	25×13	13.8 × 9.9

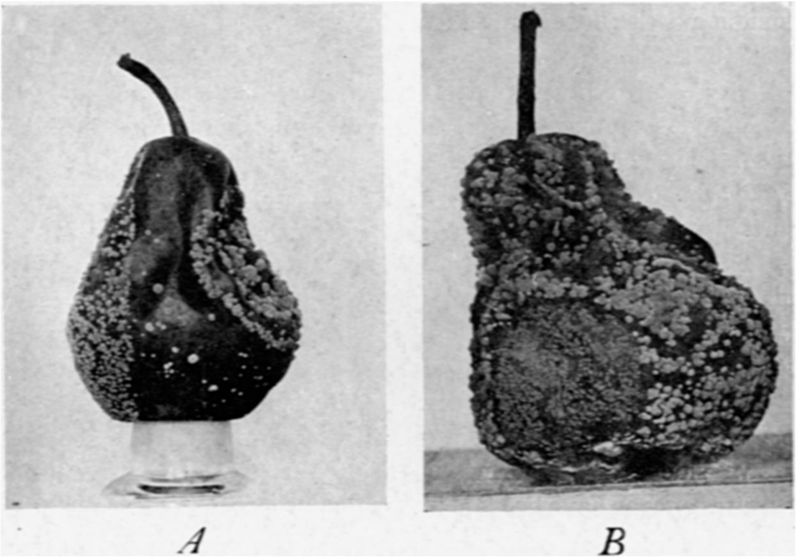

FIG. 4.—*A*, local *Sclerotinia* and European *S. fructigena* on the same pear; *B*, local *Sclerotinia* on a pear surrounded by *S. fructigena* taken from fruit sent by Dr. GY DE ISTVANFFI of Budapest.

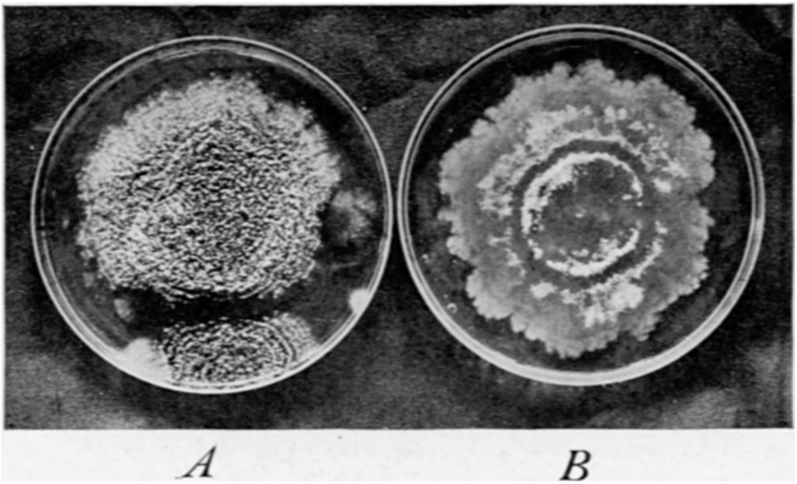

FIG. 5.—*A*, local *Sclerotinia* from plums on 1 per cent sugar, 1 per cent malic acid, and 6 per cent gelatin medium; *B*, *S. fructigena* from Europe on the same medium; both plates had the same external conditions; in both plates the gelatin is liquefied in *B* sooner and to a greater extent.

Before attempting to give the size of the conidia of the American brown-rot fungus, it was considered necessary to make a series of comprehensive measurements of the spores taken from fruit from different parts of the country. Such measurements were made. The method of this work was that of the ordinary laboratory procedure. An ocular micrometer having a scale value of 3.6 μ was used. Unconscious selection was avoided by measuring all the spores that arranged themselves in bunches on the slide, or always measuring the one nearest the right side of the eyepiece scale. Care was taken to allow the spores to become fully turgid in the water before the measurements were started.

The results obtained in these measurements are of considerable interest from another point of view. Woronin and Pollock (20) have suggested that these conidia vary in size to a considerable degree according to the host or culture. Others suggest that light and darkness also cause a variation in size. In none of these instances, however, is the method of measurement mentioned or the number of conidia measured. In the results obtained in this study no such variation was ever in evidence. On the other hand, when all the measurements were done and the figures computed for a mean, variation in size of conidia was found to be practically nothing.

SPORE MEASUREMENTS

(In each case the upper row of figures represent microns, and the lower row the number of spores of that size.)

Spores from mummied plums sent by J. W. Adams, Franklin, Ind.

No. spores measured	Length										Mean
145	11.5	12.2	13	13.7	14.4	15.1	15.8	16.6	17.2	18	14.4 μ
	3	4	13	20	50	27	19	6	1	2	
	Width										
	7.2	7.9	8.6	9.4	10.2	10.8	11.5	12.2	.....	.....	9.4 μ
	4	23	31	47	19	11	7	3	.....	.....	

SPORES FROM MUMMIED PLUMS SENT BY F. K. HACKETT, LACONIA, N.H.

No. spores measured	Length											Mean
107	13 4	13.7 7	14.4 12	15.1 31	15.8 14	16.6 14	17.2 7	18 13	18.7 3	19.4 1	20.1 1	15.1 μ
	Width											
	8.6 8	9.4 8	10.2 21	10.8 34	11.5 23	12.2 11	13 2	....	....	....	....	10.8 μ

SPORES FROM MUMMIED APRICOTS SENT BY E. H. SMITH, BERKELEY, CAL.

No. spores measured	Length												Mean
146	12.2 2	13 7	13.7 12	14.4 26	15.1 30	15.8 21	16.6 15	17.2 11	18 7	18.7 5	19.4 6	20.1 4	15.1 μ
	Width												
	8.6 12	9.4 11	10.2 29	10.8 43	11.5 26	12.2 15	13 5	14.4 3	15.1 2	....	....	....	10.8 μ

LOCAL SCLEROTINIA ON CHERRIES

No. spores measured	Length											Mean
133	11.5 2	12.2 7	13 13	13.7 15	14.4 28	15.1 36	15.8 14	16.6 6	17.2 6	18 5	19.4 1	15.1 μ
	Width											
	7.9 17	8.6 34	9.4 34	10.2 28	10.8 14	11.5 3	12.2 3	....	....	....	....	9 μ

LOCAL SCLEROTINIA ON APRICOT

No. spores measured	Length											Mean
166	11.5 2	12.2 11	13 18	13.7 27	14.4 41	15.1 21	15.8 17	16.6 4	17.2 8	18 2	18.7 3	14.4 μ
	Width											
	7.2 4	7.9 11	8.6 37	9.4 49	10.2 28	10.8 14	11.5 16	12.2 7	....	....	....	9.4 μ

LOCAL SCLEROTINIA ON BALDWIN APPLE

No. spores measured	Length												Mean
	12.2	13	13.7	14.4	15.1	15.8	16.6	17.2	18	18.7	19.4	20.1	14.4 μ
	5	14	41	62	32	21	13	17	16	13	9	2	
245	Width												
	7.9	8.6	9.4	10.2	10.8	11.5	12.2	13	....	....	....	....	10.2 μ
	11	24	41	62	42	39	17	9	....	....	....	....	

CONIDIA OF *S. fructigena*, FROM FRUIT SENT BY DR. GY DE ISTVANFFI, BUDAPEST

No. spores measured	Length										Mean
	18	18.7	19.4	20.2	20.8	21.6	22.3	23	23.7	24.4	21.6 μ
	14	21	27	30	35	49	13	6	4	2	
201	Width										
	8.6	9.4	10.2	10.8	11.5	12.2	13	13.7	14.4	.....	10.8 μ
	7	18	50	62	31	19	8	3	3	.....	

NIDIA OF *S. fructigena*, FROM AN AMERICAN QUINCE WHICH HAD BEEN INOCULATED WITH CONIDIA SENT BY THE GOVERNMENT EXPERIMENT STATION AT DAHLEM (BERLIN)

No. pores asured	Length														Mean
	....	17.2	18	18.7	19.4	20.2	20.8	21.6	22.3	23	23.7	24.4	25.1	25.8	21.6 μ
	1	4	16	7	18	22	23	64	24	12	5	3	2	1	
202	Width														
	8.6	9.4	10.2	10.8	11.5	12.2	13	13.7	14.4	15.1	15.8	16.6	....	....	10.8 μ
	10	11	19	67	21	25	15	19	11	1	2	1	....	....	

CONIDIA OF *S. fructigena*, ON A PEAR

No. pores asured	Length															Mean
	18	18.7	19.4	20.2	20.8	21.6	22.3	23	23.7	24.4	25.1	25.8	26.5	27.2	27.9	22.3 μ
	4	4	10	16	24	47	82	28	22	21	25	10	5	2	3	
303	Width															
	10.2	10.8	11.5	12.2	13	13.7	14.4	15.1	15.8	16.6	17.2	18	....	....	....	21.2 μ
	1	12	49	61	48	45	46	32	4	3	1	1	....	....	....	

CONIDIA OF *S. cinerea*, FROM FRUIT SENT BY DR. G. LUSTNER, GEISENHEIM

No. spores measured	Length										Mean
181	11.5	12.2	13	13.7	14.4	15.1	15.8	16.6	17.2	18	14.4 μ
	4	15	24	30	44	34	18	5	5	2	
	Width										
	8.6	9.4	10.2	10.8	11.5	12.2	13	13.7	14.4	....	10.8 μ
	7	14	31	49	24	25	13	9	9	....	

Number of American brown-rot conidia measured, 942; average size, 14.7×9.9 μ.
Number of conidia of *S. cinerea* measured, 181; average size, 14.4×10.8 μ.
Number of conidia of *S. fructigena* measured, 665; average size, 22.1×11.2 μ.

Asci and ascospores

Some attention has been given to the size of the asci and ascospores of *Sclerotinia fructigena* and *S. cinerea*. In the accompanying table are given the different measurements that have been made.

AUTHOR	*S. fructigena*		*S. cinerea*	
	Asci	Ascospore	Asci	Ascospore
Aderhold and Ruhland	120–180 × 9–12	11–12.5 × 5.6–6.8	89.3–107.6 × 5.9–6.8	6.2–9.3 × 3.1–4.6
Reade (**22**)..............	125–215 × 7–10	10–15 × 5–8	....	....
Pollock (**20**).............	130–179 × 9.2–11.5	11.4–14.4 × 5–7	....	....

The following explanation should be given of the above measurements. The asci and ascospores of *S. fructigena* measured by ADERHOLD and RUHLAND were obtained from mummied apples in their experiments at Dahlem. Their *S. cinerea* material was the preserved material sent them by NORTON. The measurements made by READE were of fresh material sent him by NORTON. POLLOCK'S measurements were of fresh material obtained in Michigan.

In order to determine what variation in size of asci and ascospores occurs in this country, a series of measurements was made of fresh material from different states. The measurements were made in the usual way. In each instance 100 ascospores and 70 asci were measured. From the resulting figures the following table is arranged.

MEASUREMENTS OF ASCI AND ASCOSPORES

Apothecia from	Host	Asci	Ascospores
New Haven, Conn.	Peach	144–188×6.8–10.8 Mostly 162×8.6	10.8–14.4×4.3–7.6 Mostly 12.6×5.4
Grafton, Mass.	Peach	136–202×7.5–11 Mostly 169×9.4	11.5–14×5–7.2 Mostly 12×5.4
Grafton, Mass.	Plum	144–162×7.2–10.8 Mostly 151×9.3	10–14×5–7.6 Mostly 12.2×6.1
West Boylston, Mass.	Peach	133–187×6.8–10 Mostly 158×8.2	10.8–15.1×5.4–7.2 Mostly 12.9×6.1
College Park, Md.	Peach	129–194×7.2–10.8 Mostly 162×9.3	8.6–15.1×5.7–7.9 Mostly 12.2×6.4
College Park, Md.	Plum	126–183×6.5–10.8 Mostly 151×9.6	8.6–14.4×5–7.2 Mostly 11.5×6.4
Madison, Wis.	Peach	137–190×6.5–10.8 Mostly 165×9.3	10.8–15.1×5–7.2 Mostly 13.1×6.5
Geneva, New York	Peach	133–176×6.5–9.4 Mostly 160×8.4	11.5–14.4×5.7–8 Mostly 12.8×6.2
Lafayette, Ind.	Peach	135–192×7.2–11.1 Mostly 166×8.8	9.4–13.7×5.6–7.9 Mostly 12.2×6

GENERAL AVERAGE OF THE ABOVE MEASUREMENTS

Host	Asci	Ascospores
Peach	135–190×6.9–10.5 Mostly 163×8.9	10.5–14.5×5.2–7.5 Mostly 12.5×6
Plum	135–173×6.8–10.8 Mostly 151×9.4	9.3–14.2×5–7.4 Mostly 11.8×6.3

It is seen that the results here obtained correspond closely with the measurements given by POLLOCK and READE, indicating that the same species was considered in all three cases. It is further noted that these measurements correspond with those given by ADERHOLD and RUHLAND for the European *S. fructigena* and are very little larger than those given by them for their *S. laxa* which they obtained from apricots. It is to be remembered that in the case of both these species very few measurements have been made, and that a more comprehensive study may reveal a wider variation than is here indicated.

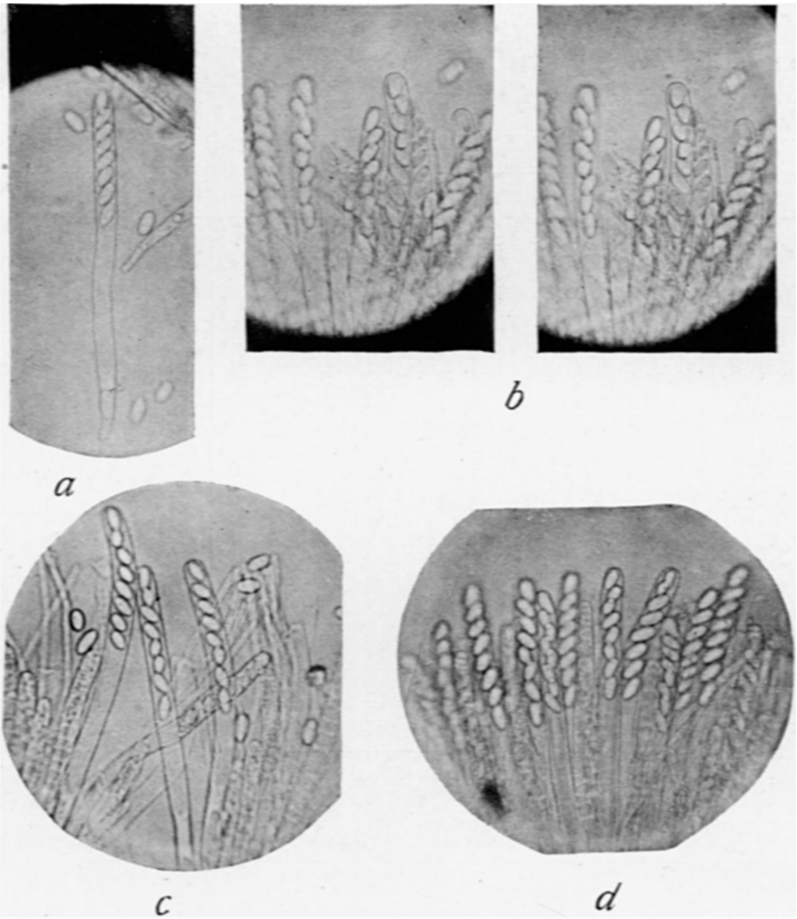

FIG. 6.—Asci and ascospores: *a*, ascus from Maryland plum; *b* and *c*, asci and ascospores from Maryland plums; *d*, from Maryland peach; all ×400.

Conclusions

The 300 experiments on different fruits show in every instance a wide difference between the *S. fructigena* of Europe and the local brown rot. First, they differ in the rate of growth, the former being much slower than the latter (fig. 3). Second, the conidial tufts do not agree in size, shape, or color. The *S. cinerea* when grown on plums, pears, apples, and quinces agrees in practically every instance with the local *Sclerotinia*.

When grown in pure culture, the European *S. fructigena* never agreed with the local form (fig. 5); 300 cultures of each were made. The conidia of the former are larger than those of the latter. Those of the latter, however, agree in size with the conidia of *S. cinerea*.

While the asci and ascospores of the European *S. fructigena* and the American form apparently correspond in size, there are differences that remain distinct. The ascospores of the former are sharply pointed at each end and are free from oil droplets, while the ascospores of the latter are rounded at the ends and possess oil droplets (fig. 6). No exception was found to this rule.

The American brown rot of stone fruits is not identical with *S. fructigena* occurring in Europe on pome fruits. It agrees more nearly with *S. cinerea* and should be referred to that species.

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